SOLAR STORMS & THE AURORA

BACKGROUND:

This section is designed to model a systematic approach coordinating solar and terrestrial data NASA scientists utilize to understand the Sun-Earth Connection—the chain of cause-effect relationships that begin with solar activity and end in the deposition of energy in the upper atmosphere. In studying the composition and properties of the solar wind during solar maximum, scientists have traced the failure of space missions, blackouts/power outages on Earth, and emissions of dangerous radioactive particles to the solar wind's interactions with Earth's magnetosphere. From the classroom, students can quantify disturbances in the Earth's magnetic field near the ground caused by the solar wind and then use real-time satellite data to predict geomagnetic phenomenon such as the aurora.

Every day life begins and ends with our Sun. As the Earth has cycles (and seasons), our yellow dwarf star has an eleven-year cycle of its own—the solar cycle. During solar maximum, activity below the Sun's surface can generate a large number of sunspots and solar flares. On occasion, an enormous burst of energetic particles (plasma) is propelled from the Sun's corona (coronal mass ejection) and blows past Pluto. As the solar wind passes Earth it temporarily distorts our protective shield (the magnetosphere) causing charged particles to spiral down the Earth's magnetic field lines into auroral ovals above the poles.

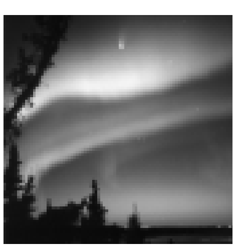
Auroral sightings appear as streaks and curtains of colored light in the night sky commonly in high latitudes near the magnetic North Pole; however, during solar maximum a CME-induced geomagnetic storm (great disturbance in Earth's magnetic field) can result in aurora sightings as far south as Arizona. Once considered a supernatural phenomenon, the occurrence of auroras can be predicted with the use of planetary index, Kp, calculated by solar and terrestrial instruments to represent the effect of a particular change in Earth's magnetic field.

In the early 1990's, NASA collaborated with other space agencies to examine the structure and dynamics in the solar interior, the driving forces behind solar activity, and the effects of the Sun's variability on Earth. SOHO (Solar and Heliospheric Observatory) is a joint effort between NASA, ESA (European Space Agency) and ISAS (Institute for Space and Astronautical Space) of Japan that provides an uninterrupted view of the Sun allowing us to study its internal structure and outer atmosphere and the origin of solar wind. ACE (Advanced Composition Explorer) was designed to determine elemental and isotopic compositions of plasma particles along with their energy and resulting magnetic intensity. Another satellite, IMAGE (Imager for Magnetopause-to-Auroral Global Explorer) provides a window to view the Earth's magnetosphere and its interactions with the solar wind at night and day during geomagnetic storms. Coordinating data from these satellites enables NASA scientists to understand the complexities of space weather and agencies like NOAA (National Oceanic and Atmospheric Administration) to issue advance warning of approaching geomagnetic storms.

In these activities, students will learn how satellite data can be used to help NASA scientists measure the effect of Sun's variability on Earth through changes caused by magnetic fields. Students will also discover that they can detect changes in the Earth's magnetic field as a result of space weather by using a simple magnetometer. Through collecting and analyzing real-time data from satellites, students carry out the same duties as a NASA astronomer by using research, mathematics and technology.

Soda Bottle Magnetometer, the hands-on classroom activity, is student-created and aligned with the National Council of Teachers of Mathematics (NCTM) standards, the National Science Education (NSE) standards, and the National Educational Technology (NET) standards. Given a set of materials and instructions, students will work in groups to construct and collect data from an instrument that measures changes in the Earth's magnetic field. Through data analysis, acquisition of satellite data from the Internet, and interpretation, students will use properties of space weather to predict the occurrence and sightings of the Aurora Borealis worldwide.

Students will work in small teams to construct a device, make observations and collect data on the disturbance of Earth's magnetic field during a geomagnetic storm. Coordinating data from SOHO, ACE and IMAGE will allow students to predict the time and location of aurora sightings using a simple soda bottle magnetometer. The objectives of the activity are (1) to provide students with a concrete example of the technology used by NASA scientists, (2) to provide an opportunity to explore effects of solar variability on Earth, and (3) to discuss this phenomenon in terms of patterns and trends within real and viable data. This activity will enhance students' ability to recognize patterns in qualitative and quantitative information through data analysis and direct application in real-life occurrences.



NATIONAL STANDARDS:

Mathematical (NCTM) Standards

- Use mathematical models to represent and understand quantitative relationships.
- Analyze change in various contexts.
- Understand measurable attributes of objects and the units, systems, and processes of measurement.
- Apply appropriate techniques, tools, and formulas to determine measurements.
- Build new mathematical knowledge through problem solving.
- Solve problems that arise in mathematics and in other contexts.
- Communicate mathematical thinking coherently and clearly to peers, teachers, and others.
- Analyze and evaluate the mathematical thinking and strategies of others.
- Create and use representations to organize, record, and communicate mathematical ideas.
- Develop and evaluate inferences and predictions that are based on data.
- Use the language of mathematics as a precise means of mathematical expression.
- Recognize and apply mathematics in contexts outside mathematics.

National Science Education Standards (NSES)

- Science as Inquiry
  Abilities necessary to do scientific inquiry
  Understandings about scientific inquiry
- Magnetic fields
  Space weather and solar cycle
- Science and technology
  Understanding about science and technology
- History and nature of science
  Science as a human endeavor

Technology for All Americans (ITEA)

- Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.
- Students will develop an understanding of the role of society in the development and use of technology.
- Students will develop an understanding of the attributes of design.
- Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
- Students will develop an understanding of and be able to select and use construction technologies.

Technology (NET) Standards

- Follow step by step directions to assemble a product.
- Recognize communication systems allow information to be transferred from human to human, human to machine, and machine to human.
- The use of symbols, measurements, and drawings, promotes clear communication by providing a common language to express ideas.
- Design involves a set of steps that can be performed in different sequences and repeated as needed.
- Brainstorming is a group problem-solving design process in which each person in the group presents ideas in an open forum.
- Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.
- Use data collected to analyze and interpret trends to identify the positive or negative effects of a technology.
- Interpret and evaluate the accuracy of the information obtained and determine if it is useful.

INSTRUCTIONAL OBJECTIVES:

Students will be able to :

- Use metric system to construct and collect measurements from the magnetometer.

- Measure, record and graph relationships to interpret data from the soda bottle magnetometer .
- Analyze data to determine disturbances in Earth's magnetic field from data.
- Recognize a high-intensity magnetic field of solar wind using real-time satellite data.
- Analyze satellite data to verify changes in magnetic field from magnetometer measurements by comparing terrestrial with space instrumentation.
- Discuss correlations within satellite data and magnetometer data.
- Predict sightings of aurora in Northern and Southern Hemispheres using geomagnetic coordinate map.

VOCABULARY:

Here are some terms that are used throughout this activity and in resource materials with which your students may not be familiar. You may want to spend some time developing their understandings of the relevant concepts.

- **Aurora**—a glow in a planet's ionosphere caused by the interaction between the planet's magnetic field and charged particles from the Sun.
- **Auroral oval**—the circular band in the Northern or Southern Hemisphere where aurora are most intense at any given time.
- **Coronagraph**—a special telescope that blocks light from the disk of the Sun in order to study the faint solar atmosphere.
- **Coronal mass ejection (CME)**—a disturbance of the Sun's corona involving eruptions from the lower part of the corona and ejection of large quantities of matter into the solar wind; sometimes have higher speed, density, and magnetic field strength than is typical for the solar wind.
- **Electron**—a lightweight particle that carries a negative charge, responsible for most electric phenomena and light emission in solid matter and in plasmas.
- **Solar flare**—is a sudden and intense variation of brightness off the Sun's surface interplanetary matter, the material in between the planets in the solar system, including that within the Earth's radius and out to and beyond the outer planets.
- **Magnetic poles**—the points on Earth towards which the compass needle points; a concentrated source of magnetic force, e.g., a bar magnet has two magnetic poles near its end.
- **Geomagnetic storm**—a large-scale disturbance of the magnetosphere, usually initiated by the arrival of an interplanetary shock, originating on the Sun.
- **Magnetosphere**—the region around Earth whose processes are dominated by the Earth's magnetic field.
- **Plasma**—the fourth state of matter or low-density gas made of charged particles.
- **Solar cycle**—the regular increase and decrease (maximum and minimum) in the level of solar activity lasting 11 years.
- **Solar wind**—a continuous flow of gas and energetic charged particles.
- **Sunspot**—a dark region on the solar surface where the magnetic field is so strong that the flow of energy from below is suppressed.]

ACTIVITIES:

Preparing for the Activity

- The construction of one class soda bottle magnetometer (see instructions for construction in MAGNETISM section). Optional magnetometer is listed in Extensions.
- You can organize students in groups or pairs.

<u>Materials</u>
(for one magnetometer—4 students per group)

- 2-liter soda bottle or tennis ball canister
- 2 ft of sewing thread
- 1 small bar magnet
- 1-3 x 5 index card
- 1 mirrored dress sequin
- 1 adjustable high-intensity lamp